Status of the ExAO Testbed

Julia Wilhelmsen

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Acknowledgements

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The LAO at UCSC

We moved!

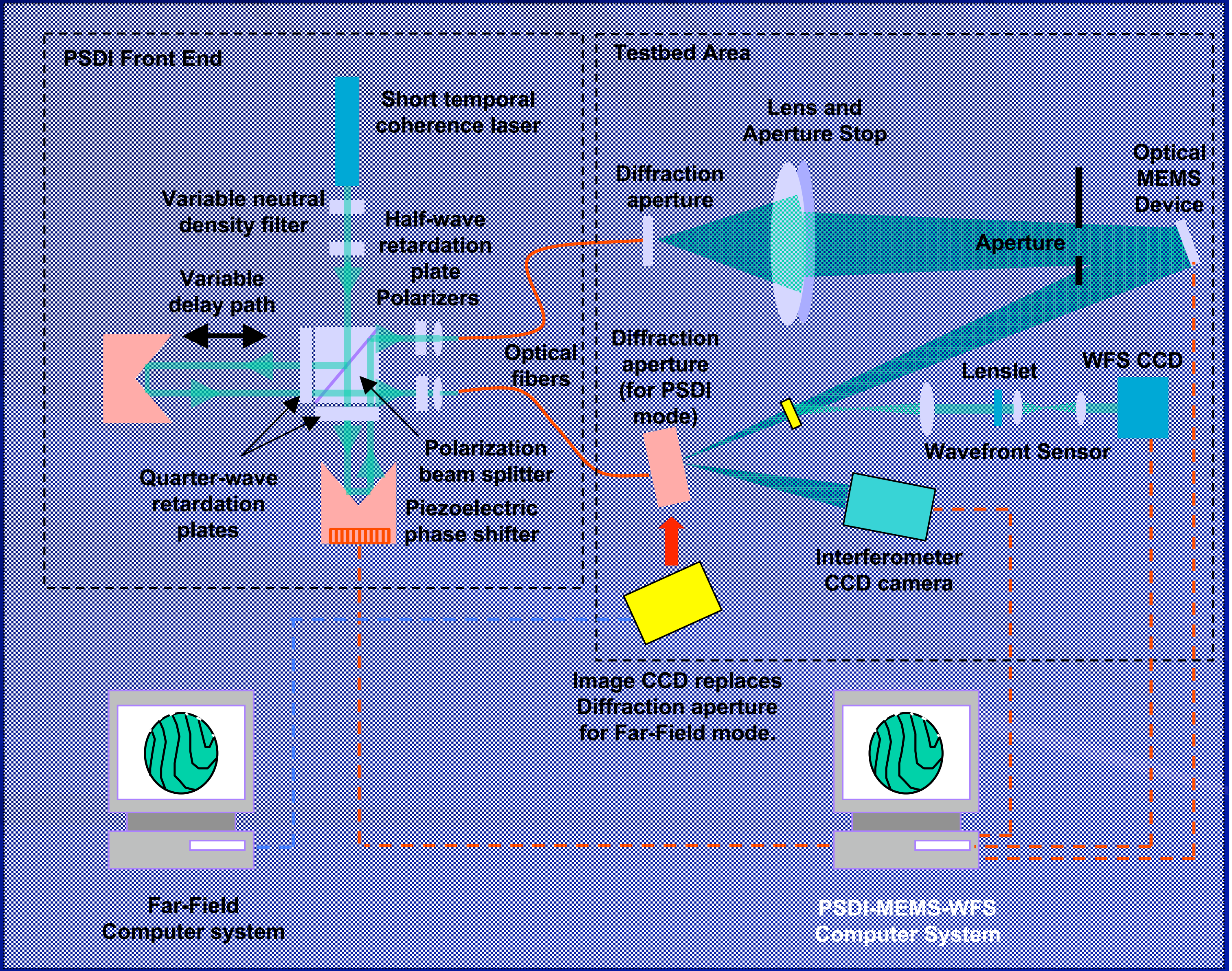
Goals of the ExAO testbed

- Demonstrate nm metrology of an optical system
- Demonstrate <2 nm RMS WFE
- Demonstrate 10^{-7} contrast at visible wavelengths and consistency with wavefront measurements
- Install MEMS deformable mirror
- Demonstrate ability to flatten MEMS to <1 nm RMS WFE over controlled frequencies
- Demonstrate contrast of 10^{-6} (goal:10^{-7}) with MEMS in place
- Demonstrate nm-accuracy measurements with a Shack-Hartmann WFS

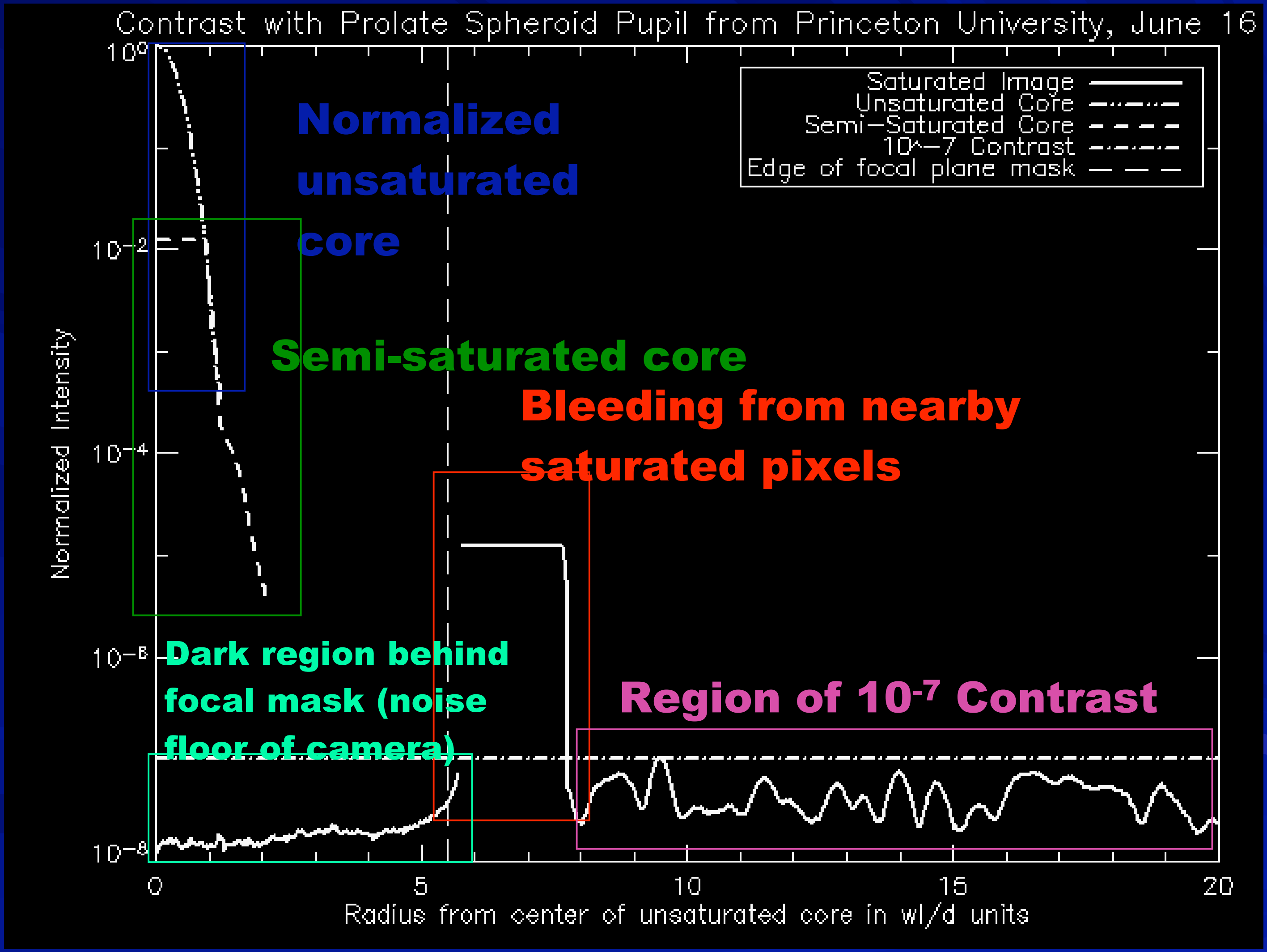
Layout of the Testbed

Features

- PSDI for built in metrology
- Simple optical design for low wavefront error
- Shaped pupils for producing regions of high contrast in the image plane

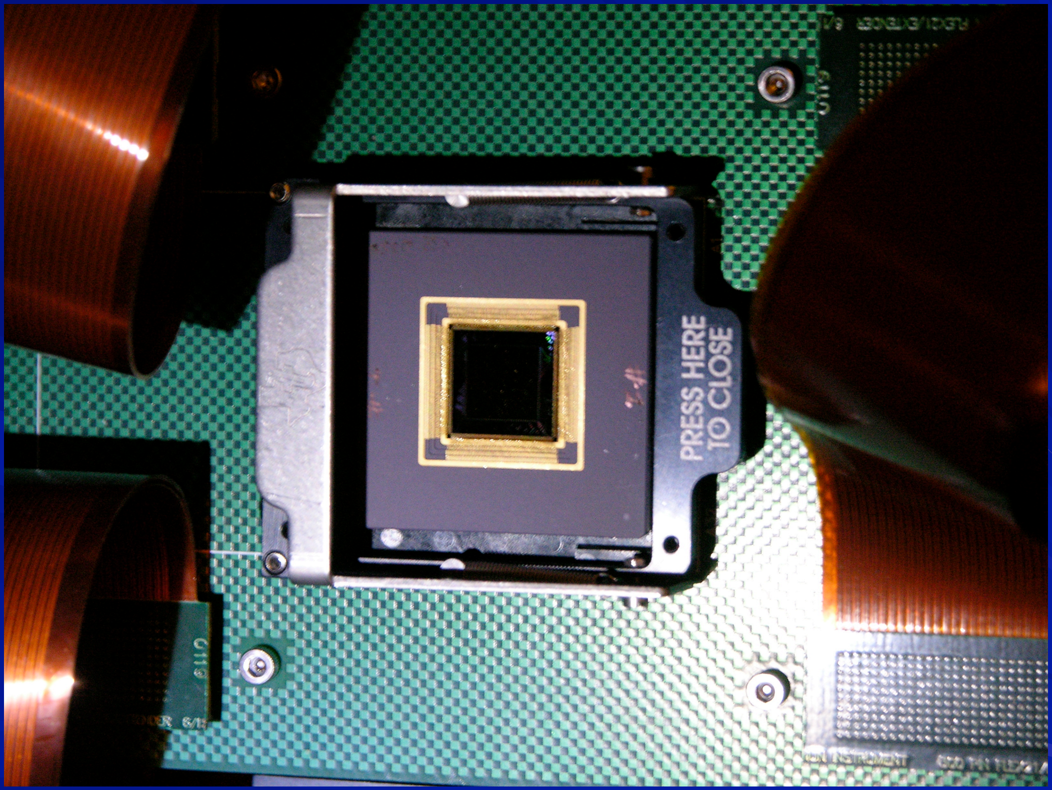


Contrast with Flat



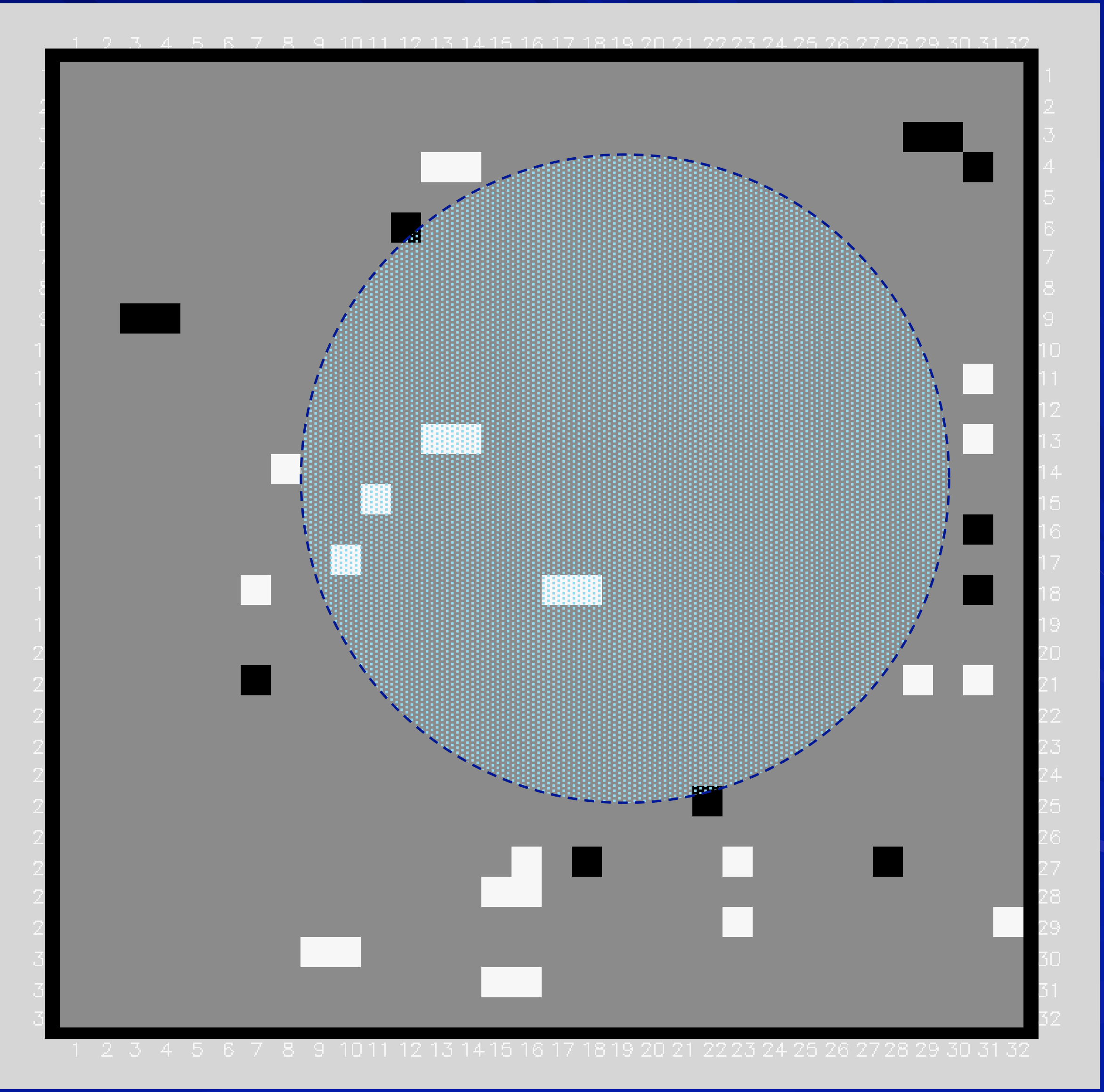
The MEMS Deformable Mirror

- We have received 4 devices from BM to date
- Each device is 10 mm on a side
- 1024 -300μm actuators
- About 1-1.5 μm stroke with 160 volts
- Approx 10 dead actuators per device
- 13 bit electronics (4-288 channel boards from Red Nun)



Engineering Lessons

- Humidity sensitive
- Correct mapping
- Dead/Bad actuator locations



Mapping/types of dead actuators

- Mapping has been corrected
  - 188 mis-mapped actuators
  - Approx. factor of 2 improvement in Flattening
- Four types of bad actuators
  - Dead Actuators that do not move
  - No response actuators that are not actively moved but “float” with their neighbors
  - Coupled adjacent actuators that move together
  - Low response actuators

Humidity Sensitivity

Oxidation caused by a combination of high voltage and high humidity =

dead actuators

Anodic Oxidation and Reliability of MEMS Poly-Silicon Electrodes at High Relative Humidity and High Voltages

Herbert R. Shea[*], Arman Gasparyan, Carolyn D. White, Robert B. Comizzoli, David Abusch-Magder, Susanne Arney
Bell Labs, Lucent Technologies, 600 Mountain Ave., Murray Hill, NJ 07974

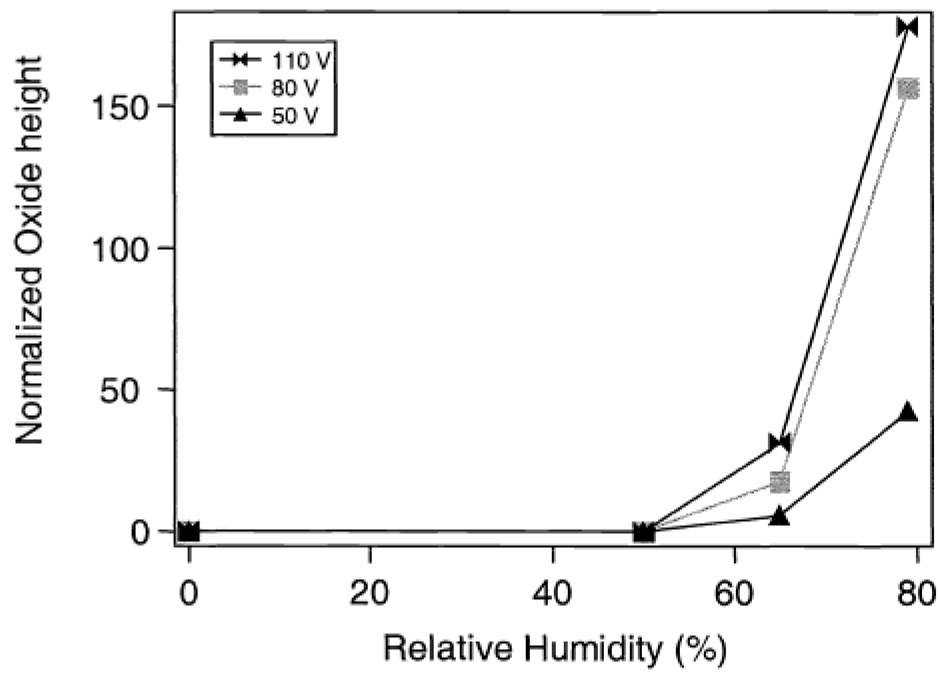
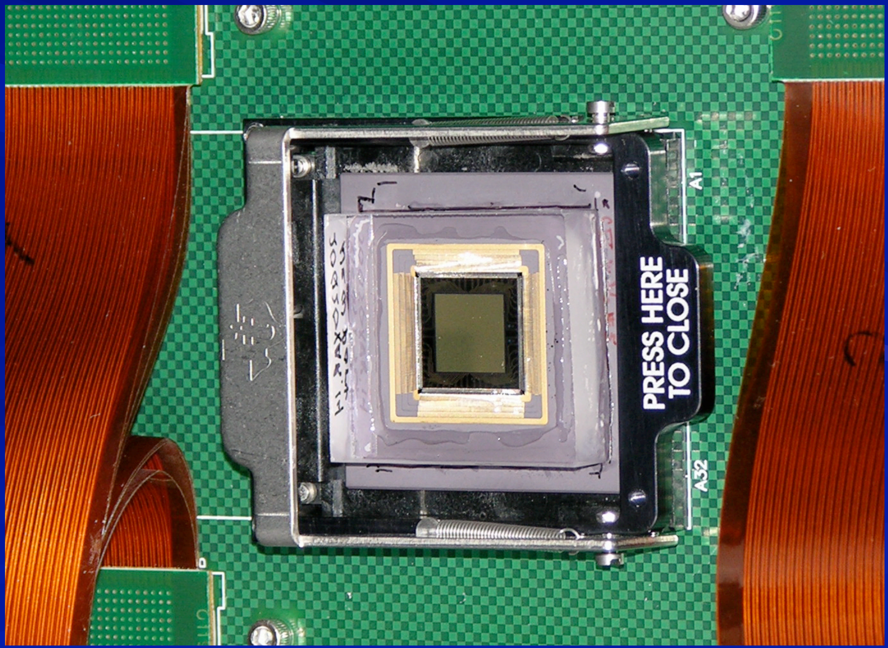


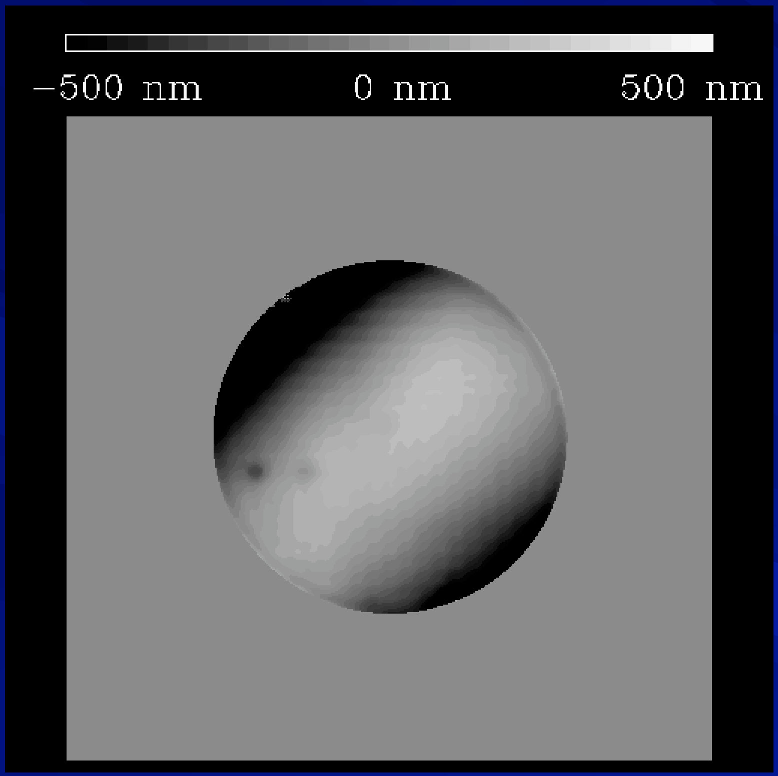
Figure 4: Plot of normalized measured oxide height on the A electrode vs. percent relative humidity after 24 hours at the indicated voltage.

Solution to humidity

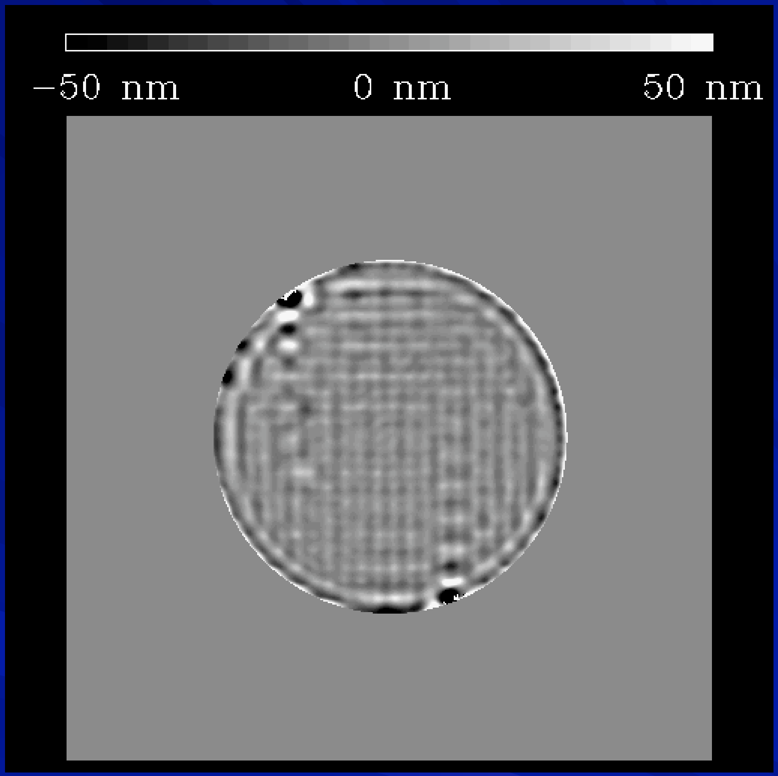
- Controlled environment (not as easy as we thought) to below 50% humidity
- MEMS device with window
- In experiments to date the window has not been a problem



Before and after wavefronts



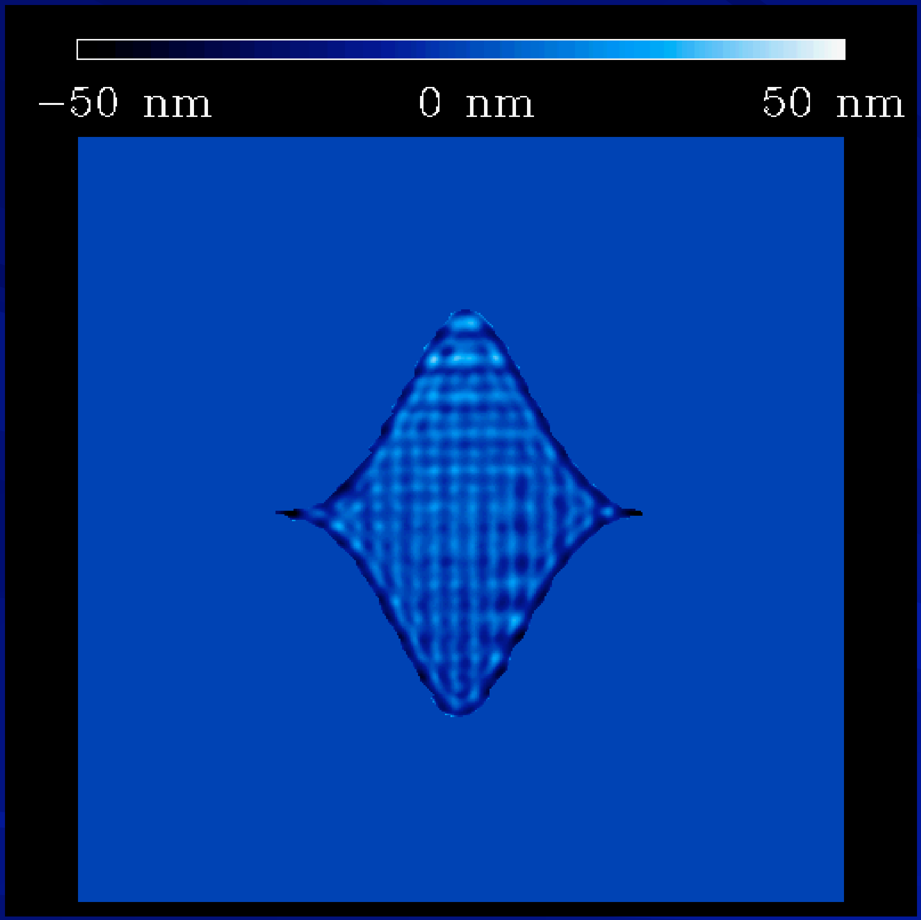
162.50 nm RMS
total wavefront error

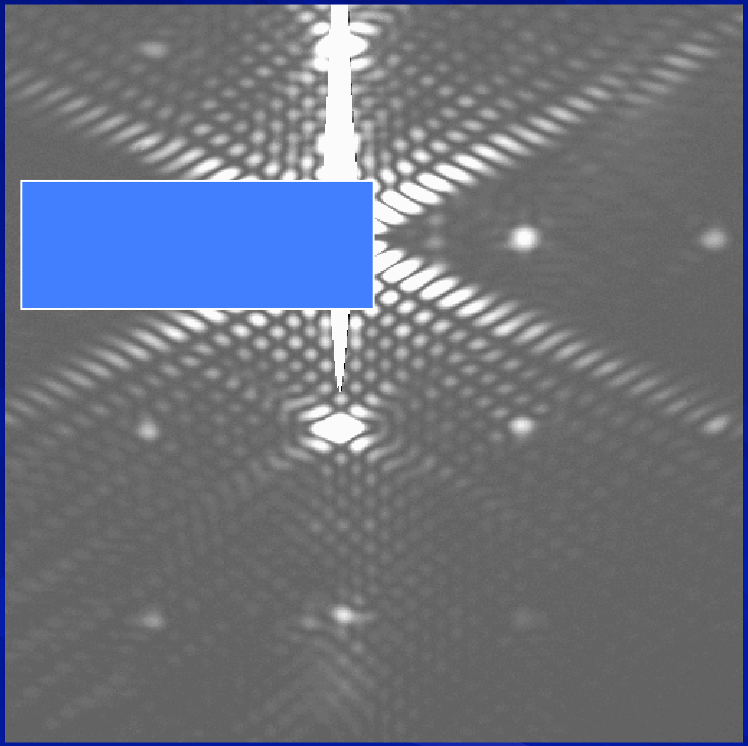


6.13 nm RMS total
2.66 nm RMS within control radius

Wavefronts taken before and after flattening on Oct 18

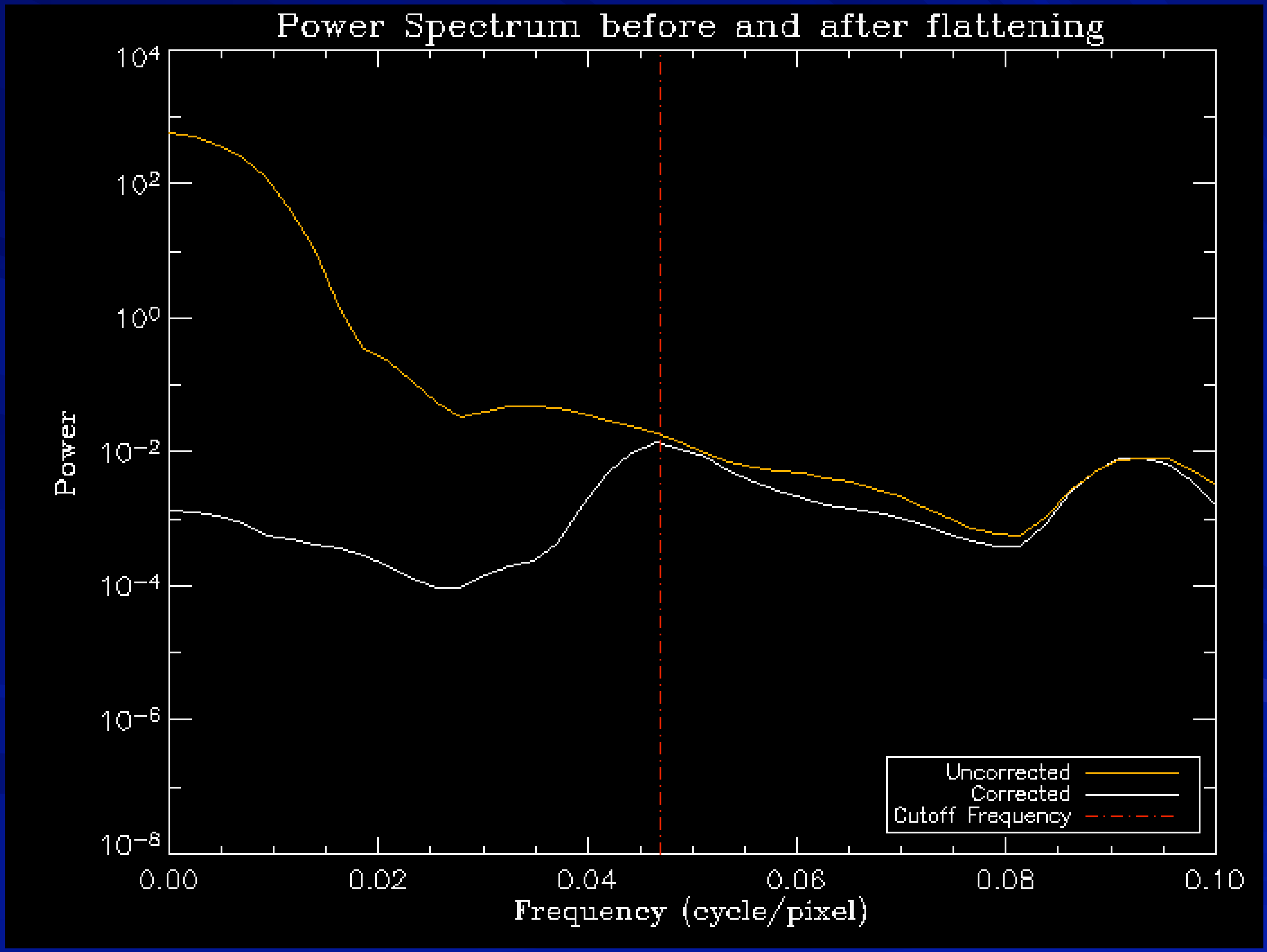
Wavefront with Prolate Pupil



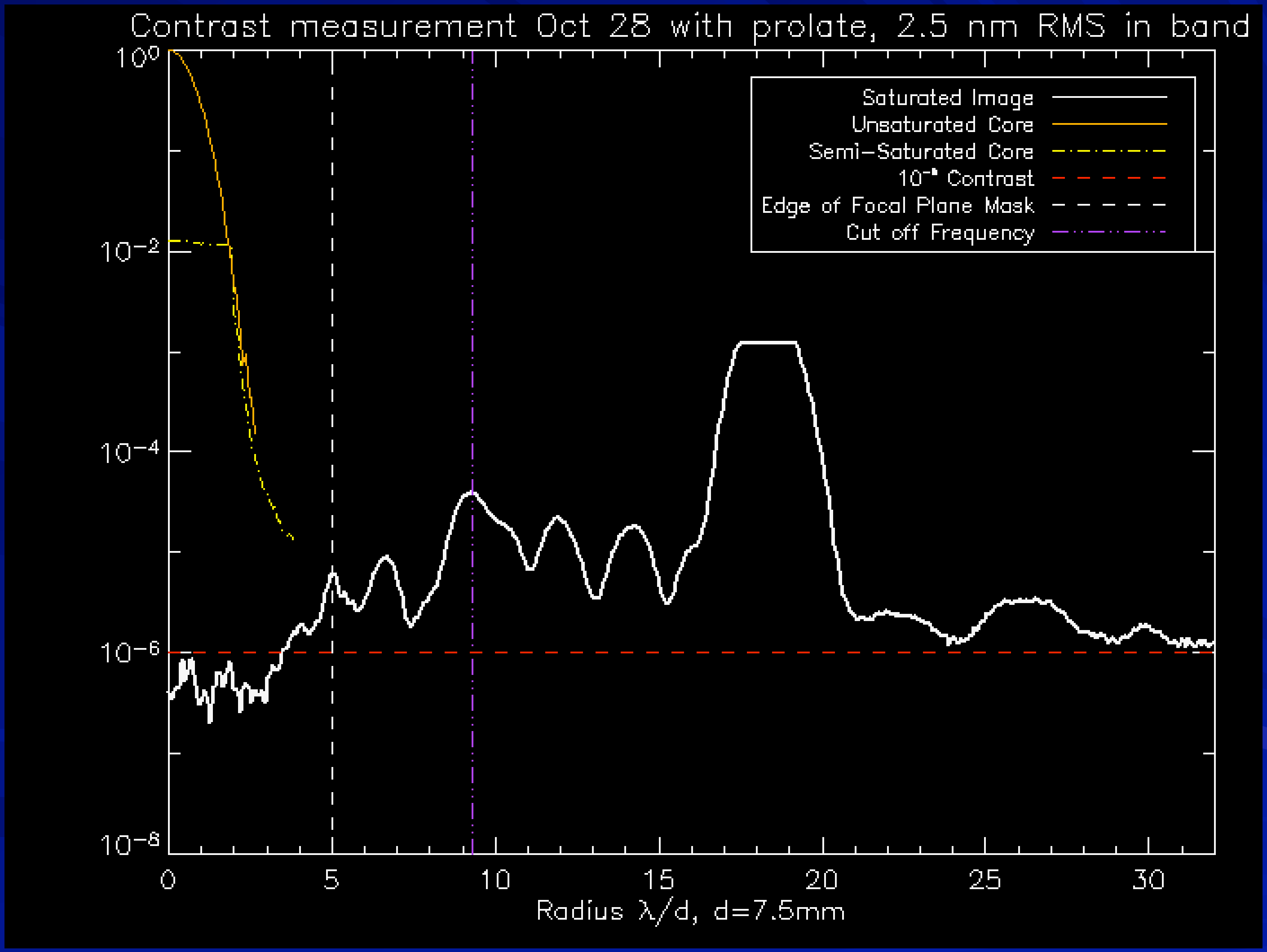


Far Field produced with prolate spheroid pupil with some saturation in the core. In contrast measurements the core is blocked.

Before and after power spectra

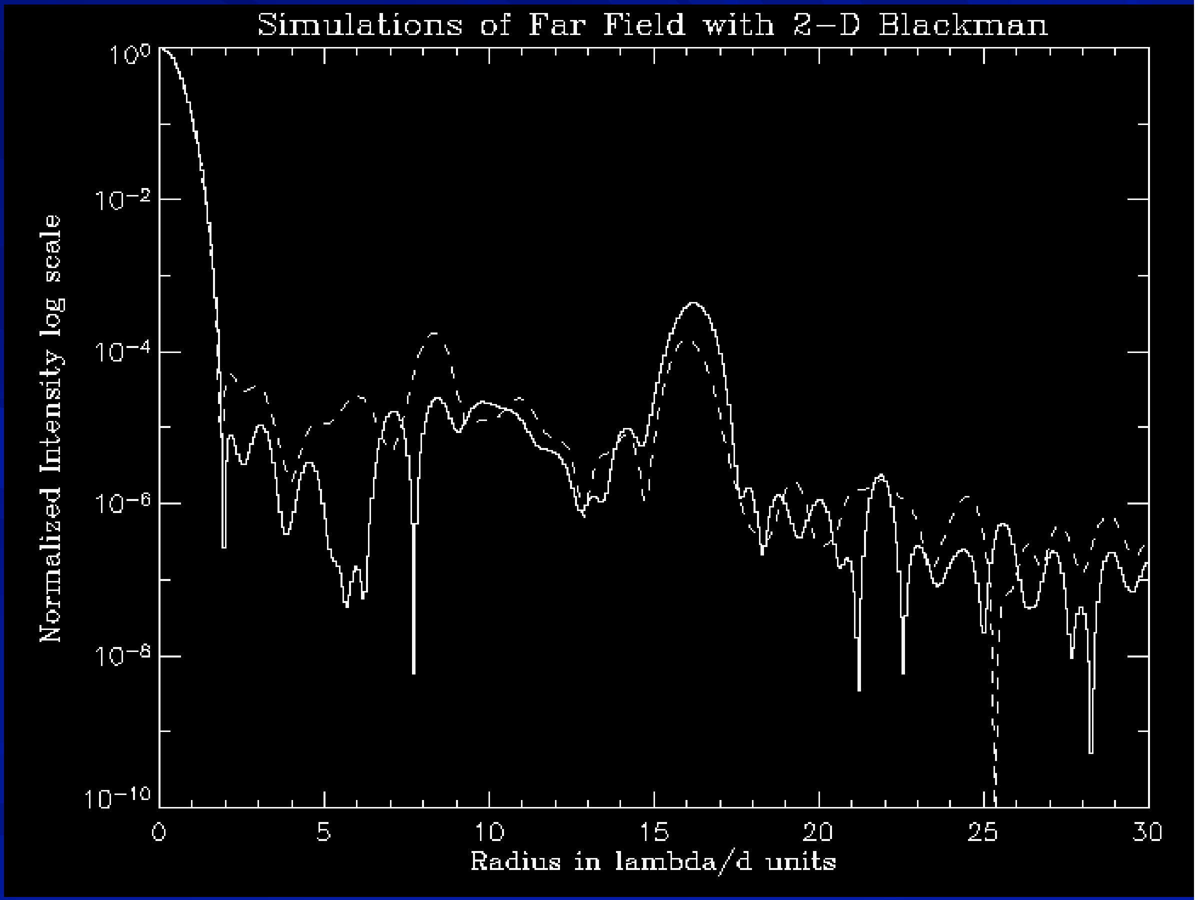


High Contrast Imaging with MEMS



Improving Contrast

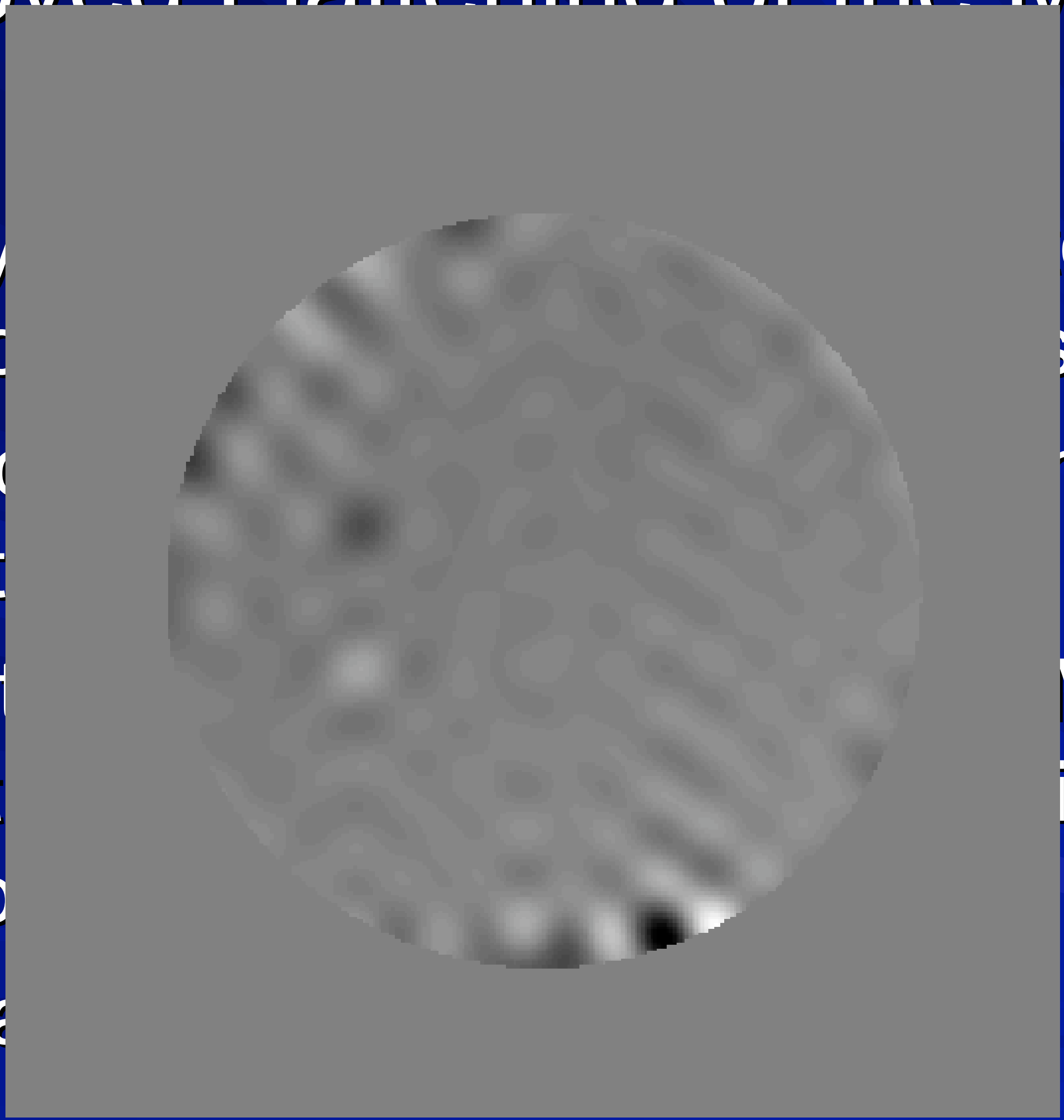
- Contrast improves by
  - Number of Actuators^2
    - Larger aperture covers more of the MEMS
    - Currently limited by dead actuators on the mems
  - Wavefront error^2
    - Correct mapping improved WFE by factor of 2 translates to factor of 4 in contrast
  - Wavelength^2
    - Testbed operates in the visible, final instrument will be IR- factor of 10 in contrast



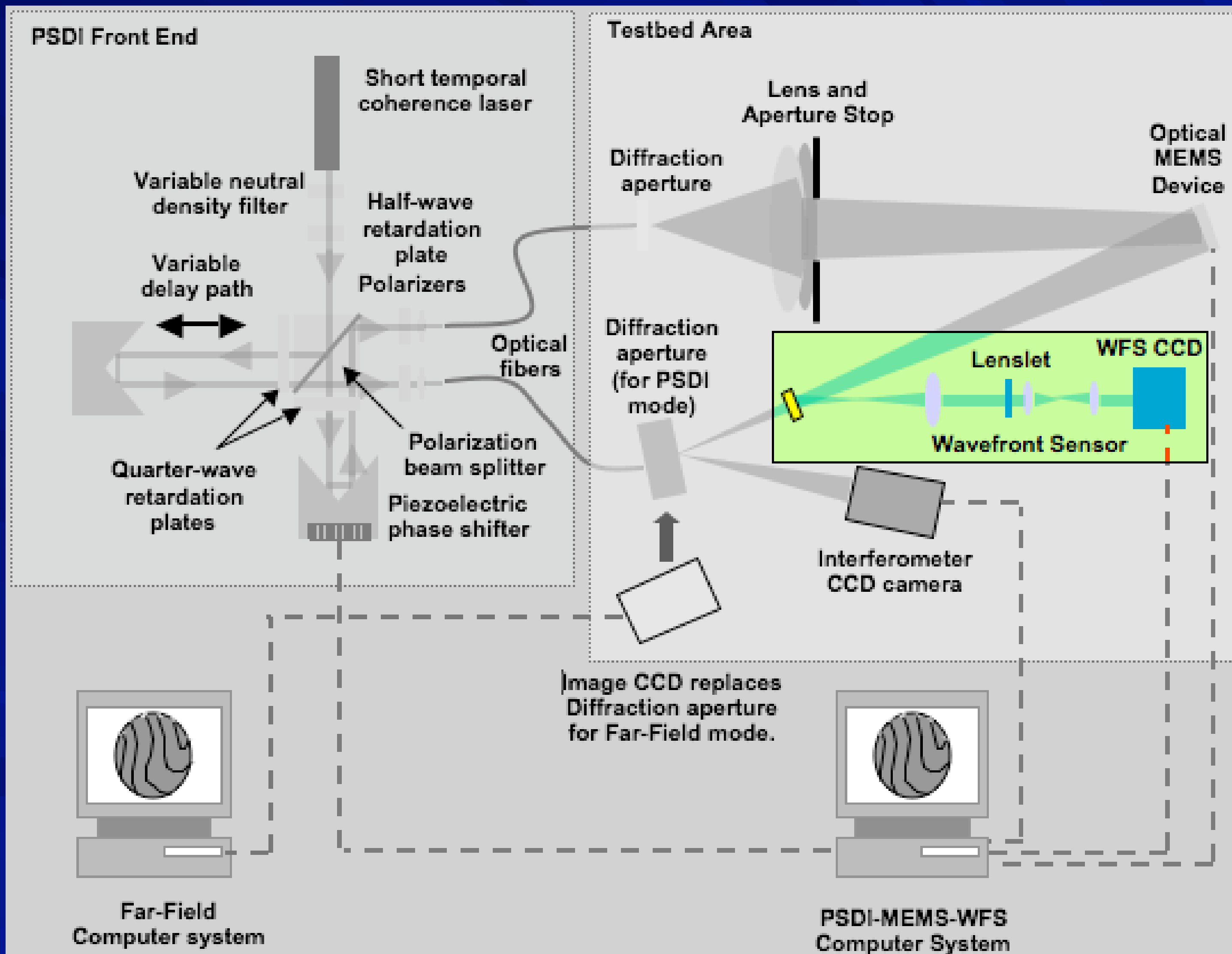
Improved Flattening of the MEMS

Lisa Poy… …o help us trac… …system.

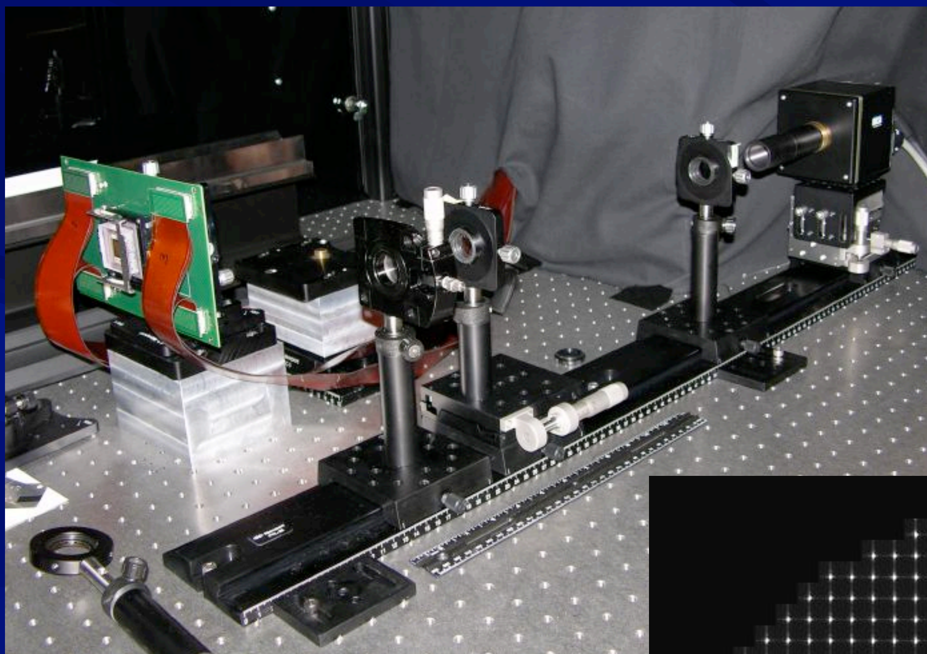
- Limitec… …ne lowest…
- Stabilit… …MS) on short t… …ions of the clo…
- "bad" a…

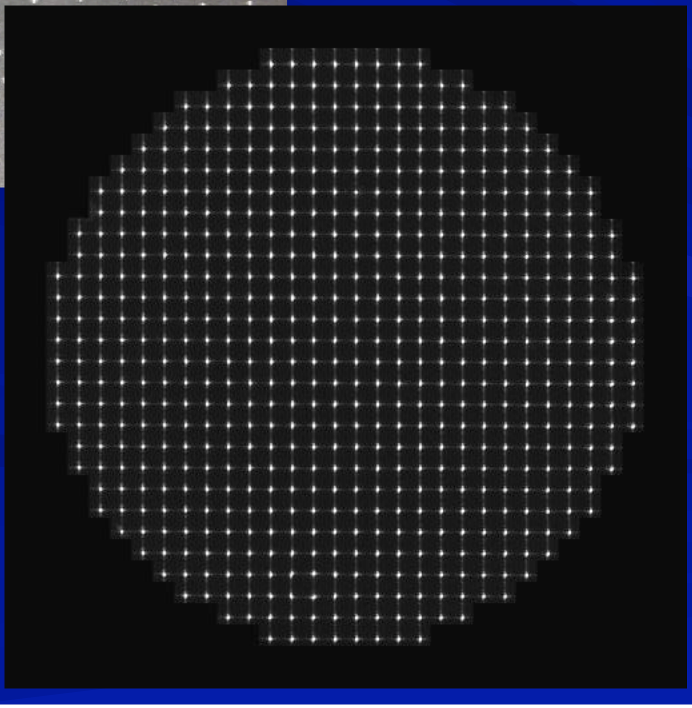


Shack-Hartmann WFS



Shack-Hartmann WFS





Features

- 32x32 Sub-Apertures
- Optimal modal Fourier controller

Conclusions and Next Steps

- Improve flattening of MEMS device
  - Identify and correct “bad actuators”
  - Improve short term stability of system
- Improved far field data with the MEMS
  - Larger aperture (new MEMS with fewer dead actuators)
- Wavefront sensor
  - Installation complete
  - Next steps: finish alignment, close the loop